Social Dilemma in the Adoption of RPKI and its Possible Resolution through Altruism and Bounded Rationality.

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Internet Routing with BGP

- In the Internet, data (packets) are transferred using IP addresses.
- The Internet is composed of Autonomous Systems (AS), each managing its own IP address range (route).
- ASes: exchang route information via BGP, propagating it across the network.
- Malicious AS can exploit this system by announcing false routes, leading to traffic interception or loss (BGP hijacking).



RPKI (Resource Public Key Infrastructure)

- RPKI: validate the received address announce
 - ROA (Route Origin Authorization): Allows AS to register their route information, proving ownership of IP address ranges.
 - ROV (Route Origin Validation): Enables AS to verify received route announcements, rejecting spoofed routes.



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Cost and Benefit of RPKI Adoption

- Each AS decide whether to adopt ROV/ROA considering its benefit and cost
 - Benefit: Reduction of route hijacking risk
 - Cost: Server setup, Risk of mis-operation (leading address is mistakenly validate as malicious)
- While the cost is constant, the benefit depends on the adoption status of other ASes.



Social Dilemma

- Both ROA and ROV should be adopted by Origin AS and Receiver AS, respectively.
 - AS the number of ROV adopted ASes increase, hijack risk decreased for ROA adopted AS and vice versa => chicken egg problem
 - If the upstream AS adopt ROV, then downstream ASes are protected. => free riders
- ROV/ROA adoption has positive externality => spontaneous adoption leads to insufficient adoption ratio regarding to the social optimum (Social Dilemma)
 - Initial adoption is required even though such AS does not gain benefit at the time of adoption.



Adoption Status

- Due to the social dilemma, adoption evolution is slow.
 - ROA: gradually adopted
 - ROV: not explicitly announced
- US Government releases roadmap to enhance Internet Routing Security[1]
- Although the adoption ratio remains low, there has been gradual progress in adoption.
- Research Question: Why ASes spontaneously adopt ROA/ROV even in the social dilemma

[1] Press Release: White House Office of the National Cyber Director Releases Roadmap to Enhance Internet Routing Security



Altruism, Bounded Rationality

- AS behavior may not always follow perfect rationality.
- Altruism : might consider other ASes benefit (to expect mutual benefit)
 - Global altruism: consider the benefit of all other ASes
 - Local altruism: consider the benefit of connecting ASes
- Bounded Rationality:
 - ASes are uncertain for cost and benefit.
 - Due to the uncertainty, AS will make probabilistic decision





Multi-agent Simulation

- 1000 AS
- Discreate Time Simulation (e.g. month)
- In each time step, each AS decide whether adopt ROA and/or ROV based on cost and benefit calculated by the current adoption status



Multi-agent Simulation

- Cost: Proportional to the logarithm of AS size (degree of AS)
- Benefit: Proportional to the volume of sent (received) traffic being protected by the adopting ROA (ROV)



Adoption Scenario

- Without BR nor LA/GA, spontaneous adoption is never observed
- By introducing altruism and bounded rationality, both ROV and ROA are spontaneously adopted.



Cost and Benefit of total ASes

- In the early stage, the total cost (i.e., the sum of the all Ases' cost) exceeds the benefit. However, the relationship is reversed in the middle stage.
- With partial adoption, total benefit is nearly equivalent to that of full adoption, while the cost is lower than that of full adoption



Discussion

- In BR and LA/GA scenario, while ASes do not behave rationally, they achieves a global optimum that provides greater benefits to all ASes.
 - High degree centrality node (AS) has potential benefit to adopt ROV
 - High betweenness centrality node (AS) has potential altruistic benefit to adopt ROV
- When those ASes spontaneously adopt ROV by bounded rationality



Conclusion and Future Works

- Conclusion
 - Confirm the possibility of spontaneous adoption of RPKI with appropriate altruism and bounded rationality
 - Confirm that the above adoption caused by "irrational" decision making, it leads the global optimum (beneficial to all ASes) in the end.
- Future Works
 - Investigate the factors that cause regional difference in adoption (altruism, bounded rationality, or cost/benefit induced by the policy makers)
 - Estimate the required cost reduction or benefit increase to achieve social optimum.
 - Applying to other security technology (mail authentication)

Backup Slides

Varying *r* (cost ratio)

• Cost ratio is also key factor.





ROV adoption history

ROA adoption history

Backup Slides

Varying μ (degree of altruism)

• The degree of altruism seems not have much impact on adoption



ROV adoption history

ROA adoption history